THE BACTERIAL TREATMENT OF SEWAGE.

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1904.

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MORE than two years ago the writer collected certain data on this subject for the Provincial Board of Health, and has now been asked, since the Report was not printed by the Board, to furnish the information then obtained.

The bacterial treatment of sewage includes various methods of disposal, as by broad or subsoil irrigation, or contact beds, in conjunction usually with screening, or sedimentation, or chemical precipitation, or septic tanks.

As the last has excited much discussion during the last few years, let it be given the place of honour; and the following, relative to the duties to be performed by it, and by the contact bed, has been condensed from a paper read by Mr. G. H. Fowler, M.S.C., F.S.C., at a meeting of the Royal Institute of Public Health.

For the convenience of those who, like the writer, are ignorant of chemistry, the following are definitions of chemical terms appearing in this paper:—

Nitrates contain three parts of oxygen to one part of nitrogen.

Nitrites contain two parts of oxygen to one part of nitrogen.

Free Ammonia is derived from the decomposition of urine.

Albuminoid Ammonia is derived from the decomposition of animal or vegetable albuminous substances.

Septic Tank.

Its Objects.

1. To dissolve as much sludge as possible.
2. To obtain an effluent in which matters in solution are easily nitrified.
3. To obtain an effluent in which there is but little suspended matter.
4. To avoid creating a nuisance.

Its Action.

1. As no bacteria are known which can deal with mineral matter, no road washings, etc., should be admitted to the tank without first passing through a catch pit or grit chamber; and surface and subsoil water should be excluded if possible.

In a new septic tank anærobic action commences slowly, hence, if the ultimate flow passes in at first, sludge will rapidly accumulate before septic action is established.

2. The primary duty of the septic tank is to so break down and change the soluble matters in the sewage that the effluent is readily nitrified, and, even if but little reduction of sludge takes place, this action alone would justify the use of the septic tank.

It is believed possible that too slow a flow through the tank might produce a putrid effluent, actually poisonous to the nitrifying bacteria.

3. The ultimate product of septic action upon the sludge, besides the soluble substances and the gases, methane or marsh gas, carbonic acid, hydrogen and nitrogen, is a very finely suspended matter, partly of the nature of humus, partly mineral, such as finely divided clay, or sulphide of iron, if iron salts are present in the sewage, and this passes with the effluent on to the contact beds or irrigation area.

4. The residual sludge can be burnt or used as manure; the silt alone is quite innocuous.

5. Covering the tank is not a real preventive of nuisance, unless the gas is collected and burnt.

Contact Beds.

Purification of the Tank Effluent.

1. To procure a good contact bed effluent or filtrate there should be but little variation in the composition of the tank effluent.

The thorough drainage of the contact bed is essential, for if the water cannot get out the air cannot get in, the lower parts of the bed become putrid and the nitrates decrease, and with their decrease comes an increase of nitrites. In such a case the bed must be rested.

2. While the effluent from the bed may continue excellent, there may be a marked decrease in capacity, and this may arise from the settling together or packing of the material, from the growth of organisms, impaired drainage, from solid matter entering and clogging the bed, or from the breaking down of the material of which the bed is composed.

The packing of the material must always occur more or less, and largely accounts for the initial decrease in capacity after the bed has been at work for a short time.

The growth of organisms is the cause both of increased efficiency and decreased capacity.

By working the bed at high speed while the effluent remains good the organisms increase with such rapidity that the bottom of the bed becomes too spongy to allow the water to drain away, and when the decrease of capacity outweighs the advantage to be derived from the increased efficiency, the bed requires a period of rest of from one to two weeks, during which the superfluous organisms will be consumed, and the capacity be increased.

Such a period of rest should never exceed two weeks, as the bed tends to dry up and the activity of the bacteria ceases.

Mr. K. F. Campbell, M. Inst. C. E., gives the following decrease of capacity in contact beds at Huddersfield :—

Class of Influent.	Loss of capacity per cent.	In weeks.
Crude sewage	75 %	76
Chemically treated sewage	41 %	110
" "	51 %	142
" "	54 %	134
" "	37 %	68
Septic tank effluent	49 %	34

Every precaution must be taken to prevent the finer particles of material reaching the drains.

The decrease of capacity due to solid inorganic matter entering the bed will not be affected by resting, hence such matters should be retained on the surface and removed from time to time.

The disintegration of the material of a contact bed should be prevented by the use of hard, refractory material.

An attempt will now be made to describe shortly the methods of sewage disposal in a number of cities, and, as far as possible, the degree of success attained.

The information has been derived from numerous reports and papers by Professor Clowes, Messrs. Donald Cameron; Dibdin, F. I. C., F.C.S.; Thudicum, F. C. S.; Lacey; Maughan; Lieut.-Col. Jones, V.C., Ass. M. Inst. C. E.; Roechling, M. Inst. C. E.; Wike, M. Inst. C. E.; Carpenter; Alford & Shields; Campbell, M. Inst. C. E.; Rust, M. Can. Soc. C. E., and others, mostly published in the engineering press, and the reports of the Royal Commission on Sewage Disposal.

Exeter, Devonshire.

The method which has been designed and tested by Mr. Cameron is that of the septic tank with two contact beds.

Practically no sludge remains in the tank. There were 24.5 grains of suspended matter per gallon of sewage entering the tank; the tank effluent contained 10.8 grains, hence 13.7 grains were consumed in the tank, as they apparently did not take the form of sludge. After the tank effluent had passed through a coke breeze contact bed there was practically no suspended matter in the filtrate, so that the 10.8 grains entering must have been consumed or rendered soluble in the bed.

By the tank action the oxidizable matter in solution was reduced by 30.8 per cent., the free ammonia by 26.9 per cent. and the albuminoid ammonia by 17.5 per cent.

The united action of the tank and beds caused an average diminution of dissolved oxidizable organic matter equal to 80.9 per cent., of free ammonia 54.9, and of albuminoid ammonia of 63.2 per cent., while practically all matters in suspension were consumed or rendered soluble.

Pawtucket, R. I.

The following results were obtained by septic tank and contact bed:—

The sludge remaining in the tank amounted to 6.51 cubic yards per 1,000,000 gallons of influent, of which 81.75 per cent. was water, leaving 1.19 cubic yards of solid sludge per 1,000,000 gallons. As for each million gallons 2.24 cubic yards of suspended matter entered the tank and 1.19 were left in it, 1.05 cubic yards per million gallons, say 47 per cent., must have been consumed, rendered soluble by septic action, or escaped in the effluent.

Further, 41.5 per cent. of the organic matter, as represented by the albuminoid ammonia, and 2.7 per cent. of the free ammonia, were removed by the tank action.

The tank effluent was subsequently treated in contact beds with the total purification: first, by tank and sand filter of 81.7 per cent. of free ammonia, and 94.2 per cent. of albuminoid ammonia; second, by tank and filter 14, of 34.8 per cent. of free ammonia, and 69.9 per cent. of albuminoid ammonia; third, by tank and filter 15, of 43.1 per cent. of free ammonia and 71.3 per cent. of albuminoid ammonia.

Filters 14 and 15 were of assorted sizes of gravel 8 inches deep, on which, in No. 14, 3 feet 4 inches of crushed stone, and in No. 15 3 feet 4 inches of soft coal cinders, were placed.

The quantity of effluent per cubic yard of filtering material was about 100 gallons a day.

Sheffield, Yorkshire.

Here the sewage is first treated chemically and then discharged over aerating weirs into a culvert emptying into the river Don.

The degree of purification in September, October and November, 1899, was found to be 57 per cent., measured by the reduction of albuminoid ammonia, and of 46 per cent. measured by the oxygen absorbed in four hours. The precipitant used is lime.

The population is about 350,000, and the daily flow of sewage about 20,800,000 gallons, of which more than half arises from storm, ground water and manufacturers' wastes. The sludge amounts to about 180 tons a day.

Experiments with double contact beds were made in 1899, with the result that a [illegible]ly good effluent was obtained, and up to the date of the report there had been no [illegible] deal with. The secondary fine filter, however, showed a marked want of capacity, [illegible]mated quantity being 1,800,000, while they could only deal with 960,000 gallons a [illegible]t was proposed to adopt the system of double contact beds. Whether they have yet been installed the writer cannot say.

Birmingham, Warwickshire.

The daily flow of sewage is about 27,600,000 gallons, and is disposed of on a sewage farm increased in 1897 from 1,240 to 2,440 acres.

The sewage is first chemically treated, and in September, 1898, the sludge for the year amounted to 326,000 cubic yards, equivalent to 32½ cubic yards per 1,000,000 gallons.

The sludge is spread on the land, and dug in when partially dried.

For the year the farm receipts were $113,000 and the working expenses $215,000.

Oswestry, Shropshire.

The sewage of Oswestry, after sedimentation, is further purified by double contact beds.

The population is about 10,000, and the average daily dry weather flow 486,000 gallons, of which probably 186,000 are due to storm water, etc.

There is but little doubt that some septic action takes place in the tanks, and the results from the subsequent action of the contact beds are most encouraging, as shown in the following table:—

Analyses of Sewage and Effluent from Double Contact Beds in parts per 100,000.

Date.	Albuminoid Ammonia.		Percentage of Purification.
	Sewage.	Effluent.	
August 28th, 1899	1.136	0.130	89.8
September 16th, "	2.600	0.180	93.0
October 11th, "	1.860	0.191	89.8
November 18th, "	1.680	0.159	91.0
December 4th, "	1.320	0.129	90.2
" 22nd, "	1.200	0.120	90 0
January 2nd, 1900	1.140	0.120	89.4
April 10th, "	1.920	0.240	87.5
" 16th, "	1.509	0.186	87.6
July 5th, "	2.280	0.280	87.7
September 7th, "	2.040	0.240	88.2
October 2nd, "	1.680	0.210	87.5
January 22nd, 1901	1.800	0.174	90.3
February 15th, "	1.380	0.126	90.9
March 15th, "	1.380	0.108	92.2
" 27th, "	1.080	0.108	90.0
April 23rd, "	2.040	0.156	92.3

The capacity of the beds has been reduced about 30 per cent., but no further decrease has been observable for some time.

The sludge from the tanks is pumped out at intervals of from 8 to 10 weeks, mixed with fine screened ashes and readily sold to the farmers.

Aldershot, Hampshire.

The sewage of this great military camp, amounting to about 1,200,000 gallons a day, is first passed through screening and sedimentation tanks, and then disposed of by broad irrigation on a sewage farm of 131 acres, on different areas in rotation, the effluent finally discharging into the river Blackwater.

The sludge is drawn off from the tanks, mixed with the straw manure from the cowshed, allowed to rot, and then used as a dressing.

For a detailed account of this work, as also for much other valuable information on the subject, see "Natural and Artificial Sewage Treatment," by Lieut.-Col. A. S. Jones, V.C., and H. A. Roechling, M. Inst. C. E. It should be added that the work was designed and carried out by the former gentleman.

Woking, Surrey.

A population of 8,000 disposes daily of 288,000 gallons of sewage upon 43 acres of farm land, the sewage ultimately discharging into the river Wey.

In this case, also, settling tanks are used before the sewage is applied to the land.

London, England.

In 1893 the Main Drainage Committee of the County Council, by advice of Mr. Dibden, their chemist, started experiments on bacterial purification on a large scale, which have been continued to the present time.

The contact material was coke, on which the crude sewage was delivered.

The crude sewage, deprived of its larger particles by screening, lost practically the whole of its suspended matter by remaining in the contact beds from two to three hours.

The primary beds, from 4 to 6 feet in depth, effected a degree of purification of 51.3 per cent., and similar secondary beds increased this to 70.3 per cent.

The mineral road washings, etc., deposited upon the surface of the bed reduced its capacity, and Professor Clowes, chemical adviser to the London County Council, recommends that the crude sewage, before application to the contact beds, should be submitted to a process of sedimentation.

Huddersfield, Yorkshire.

Mr. Campbell, M. Inst. C. E., conducted a series of experiments, extending over three years, on the bacterial action of contact beds.

Screened Crude Sewage.

The crude sewage, having been screened, was applied first to a coarse and afterwards to a fine contact bed, and the analyses showed the albuminoid ammonia in grains per gallon to be:

Crude sewage.	Coarse bed effluent.	Fine bed effluent.	Percentage of purification.
0.437	0.155	0.090	79

From March 21st, 1899, to January 23rd, 1900, the percentage of purification was 80 per cent. At the end of that period it was found that the capacity of the bed had been reduced from 887,000 to 224,000 gallons per acre a day.

Chemical Purification.

The crude sewage was first treated with 3.5 grains of lime and 2.9 grains of copperas per gallon, and the analyses gave:

Septic tank effluent.	Coarse bed effluent.	Percentage of purification.
0.168	0.088	48
0.197	0.098	50
0.186	0.082	56

With the fine bed added, these results were increased to 73 per cent. degree of purification of the tank effluent.

Septic Tank.

The effluent showed an increased amount of suspended matter as time went on, rising from 4.6 grains per gallon for the first 6 weeks to 16.3 for the 40th to the 42nd week.

At the end of 44 weeks the sludge at the foot of the tank was 28 inches deep.

The final effluent from the two contact beds was generally turbid, often brownish, had an earthy smell, and, when kept at 80° Fahr. for 7 days, 80 per cent. of the samples became more or less putrescent.

With three fillings a week during January, March and April, 1901, the albuminoid ammonia in grains per gallon ran as follows:—

Crude sewage.	Septic tank effluent.	First bed effluent.	Second bed effluent.	Percentage of purification.
0.396	0.248	0.121	0.079	80

The loss of capacity of the beds was as follows:—

Contact bed treating.	Loss of capacity.	Period.
1. Crude sewage	75 per cent.	76 weeks.
2. Chemically treated sewage	41 "	110 "
3. " "	51 "	142 "
4. " "	54 "	134 "
5. " "	37 "	68 "
6. Septic tank effluent	49 "	34 "

Glasgow, Lanark.

There are three sewerage districts in this city, having their disposal works at Dalmarnock, Dalmuir and Braehead, the dry weather flows to be treated at these points being 16,000,000, 49,000,000 and 45,000,000 gallons per day, respectively.

At Dalmarnock chemical precipitation is employed. The sewage consists principally of manufacturing refuse charged with suspended matter varying from 20 to 250 grains per gallon.

Hydrate of lime and sulphate of alumina are used as precipitants. The treatment removes every trace of suspended matter and 30 per cent of purification is attained in the precipitation tanks. The large volume of water, 700,000,000 gallons a day, into which the clarified sewage is discharged renders a high degree of purification unnecessary, besides which the tidal flow affords still further dilution.

The 94,000,000 gallons of dry weather flow at the other two points, after precipitation, will discharge daily into a tidal flow of 3,000,000,000 gallons a day.

Experiments have also been made with a septic tank and contact beds, but the decision arrived at was not in their favour and precipitation will be employed.

Sutton, Surrey.

Precipitation tanks, originally used with lime as a precipitant, have been converted into contact beds.

There are now seven coarse and five fine contact beds, the latter used for second contact. The effluent attains a satisfactory degree of purification, and is discharged into a small creek.

The population is about 18,000, and the daily flow 550,000 gallons.

A few small septic tanks have been also constructed.

Hampton, Surrey.

The sewage of about 4,200 persons, amounting to 100,000 gallons a day, after screening, is dealt with by a system of treble contact beds.

Croydon, Surrey.

The sewage of Croydon, amounting to 5,000,000 gallons a day, has been for many years disposed of on a sewage farm of about 650 acres. The effluent discharging into the river Wandle is good, with a slight earthy smell. The farm is not now considered large enough, and it is proposed to provide contact beds to deal with 2,000,000 gallons a day.

Leicester.

The chief city of Leicestershire has a population of about 230,000, and a daily flow of 7,000,000 gallons, which is disposed of on a farm of about 1,600 acres. Since the land, however, is heavy clay, and subject to floods, it has been decided to provide 12 acres of contact beds to purify the sewage after passing through detritus tanks.

Manchester, Lancashire.

The well-known experts, Messrs. Baldwin Latham, P. F. Frankland and W. H. Perkin, Junr., were retained to report on the sewage disposal of this city.

The daily flow is about 30,000,000 gallons, which has been treated by chemical precipitation, 2.5 grains of lime and 2.25 grains of sulphate of iron being the precipitant used.

The wet sludge amounted to 4,000 tons a week, which was dumped at sea 100 miles from Manchester.

The scheme, as now approved by the corporation, provides for 92 acres of double contact beds, and 26 acres in addition for the treatment of storm water.

The precipitation of suspended matter is to be attained by a preliminary sedimentation and anærobic bacterial action in tanks, supplemented by ærobic bacterial treatment in double contact beds.

Some of the conclusions arrived at in the experts' report are as follows:—

1. That the bacterial system is the best adapted for the purification of the sewage of Manchester.

2. That it can deal with a sewage with a large percentage of manufacturing wastes.

3. That, as only a limited degree of purification can be obtained by one contact bed, multiple contact is necessary.

4. That a contact bed should be allowed sufficiently frequent and prolonged periods of rest.

5. That the sewage applied to a contact bed should be as free from suspended matter and of as uniform a character as possible.

6. That the anærobic or septic process takes place as effectively in an open tank as in a closed one.

7. That the constant water capacity of the contact beds should be about one-third of the tank capacity.

8. That each bed may safely be filled in six-hour cycles, provided that the sewage has first undergone sedimentation and septic action, and that the bed is rested one day in seven.

9. Of double contact beds it is estimated that, with one day's rest in seven, one acre for each 500,000 gallons daily is sufficient.

Leeds, Yorkshire.

This city has about 20,000,000 gallons of sewage a day to dispose of. Hitherto this has been accomplished with lime as a precipitant, but great difficulty has been encountered in the disposal of the sludge.

The corporation has purchased 2,000 acres for a sewage farm, about 14 miles from Leeds, but it is probable that some bacterial process will be adopted before the sewage is used for irrigation.

Carlisle, Cumberland.

Recent experiments with contact beds have been made under the direction of Mr. D[illegible]. At present, single contact only is used, and the effluent is stated to be fair.

Barrhead, near Glasgow,

has a population of about 10,000, and a daily flow of from 350,000 to 400,000 gallons of sewage.

The septic tank and one contact bed, constructed by the Exeter Syndicate, is used in conjunction with settling or grit tanks. After two years' operation the effluent appears good.

Providence, R. I.

In the spring of 1901 the chemical precipitation tanks were filled for the first time. There are 4 roughing and 16 finishing tanks. The roughing tanks have the following areas: Nos. 1 and 2, 10,090; No. 3, 11,760, and No. 4, 12,904 square feet. The 16 finishing tanks have each areas of 6,900 square feet.

There are 5 sludge storage reservoirs, with an average capacity of 21,000 cubic feet each. The sludge is compressed pneumatically, and will be shipped by railway as a fertiliser if found of value.

The writer has not heard whether satisfactory results have been obtained.

Ilford, Essex.

Mr. R. G. Hetherington stated in 1901 that the septic tank treatment in that place had proved a complete failure.

Three chemical precipitation tanks, though not really large enough, were utilised as septic tanks. At the end of six months the tanks were found to be practically full of solid matter; in fact, such was their condition that a man was able to walk across them. The sewage flow had made small channels for itself through the body of the solid sludge, and only passed over the weir wall in certain places. The effluent leaving the tank was very foul, and contained a large amount of suspended matter. At this period it was necessary that the tanks should be cleaned out, which proved a long and noxious process, and in the autumn of the same year they were again run as open septic tanks, and were found on this occasion to have filled up in four months. Apparently, the difference of two months in the time taken for them to fill up was caused by the different temperature, the septic tank working better under the hotter than under the colder conditions.

The writer cannot suggest satisfactory reasons for so complete a failure.

Passaic Valley.

The Passaic River has long been noted for its high degree of sewage pollution, and many suits have been brought in the Courts of New Jersey with a view to prohibiting its contamination.

The present population of five cities, four towns, the whole or parts of four townships and eight boroughs is about 520,000, having five combined and seven separate systems of sewerage.

A report on the subject was submitted in December, 1901, to the State Sewerage Commission by Messrs. R. Hering, J. J. R. Croes and W. M. Brown. Two methods only are available; its discharge into tidal waters as crude sewage or after partial purification.

If discharged into Newark Bay, it must be first purified; if in a crude state, the alternative is to discharge through an outfall sewer into 70 feet of water in the centre of New York Bay.

This would involve pumping the sewage collected through two 5-foot cast-iron mains crossing under Newark Bay to Bayonne, thence through a gravity sewer, 11½ feet in diameter and 13,000 feet long, into New York Bay, north of Robbins Reef Ledge.

The only alternative to the discharge into New York Bay is the purification on the Newark Meadows.

It is stated by the consulting engineers that the method by septic tanks and contact beds is feasible, provided a sufficiently large plant is installed; but, in the words of the report, "The cost of this method, particularly when applied to large quantities of sewage, is still a matter of doubt, arising from a lack of sufficient experience with operations on a large scale. We are somewhat uncertain as to the quantity of sludge which will be deposited in the present case and require mechanical removal. There is also still some doubt as to the best preparation of the tank effluent for the contact beds, the life of the latter, and the best details of operation."

The consulting engineers, accompanied by Mr. H. W. Clark, for a number of years in charge of the Lawrence Experiment Station of the Massachusetts Board of Health, visited several cities affording information on the subject, and finally recommended the discharge of the crude sewage into New York Bay at an estimated cost of $2,500,000.

It would appear from the foregoing—

1. That not more than 40 per cent. of the solids in suspension can be expected to be disposed of by the anærobic action of the septic tank, and that a certain amount of gradually accumulating sludge will remain to be removed. In the case of Pawtucket we have seen that this sludge amounted to 53 per cent of the suspended matter entering the tank.

Where the plant is worked systematically and carefully supervised, Mr. Roechling states that, generally speaking, 35 per cent. of the suspended matters entering the tank will remain as sludge, 25 per cent. will be destroyed or liquefied and 40 per cent. will escape in the effluent. It would seem that under such circumstances the effluent would be turbid and probably very offensive.

2. That the effluent from the septic tank requires treatment by at least primary and secondary contact beds, or irrigation, before becoming fit to enter a water-course as an innocuous liquid.

3. That sedimentation and chemical precipitation tanks will probably produce a larger percentage of sludge than septic tanks.

4. That as long as the scum on the surface is protected from the wind and is not allowed to be disturbed, the close covering of the tank is not essential.

5. That the principal object being to render the sewage innocuous, the question as to whether a sewage farm can be rendered remunerative is one of secondary importance.

6. That if sewage is to be discharged into a land-locked harbour, it should first pass through a septic tank, and no contact beds would be required.

7. That the septic or other tanks, however useful under certain conditions, should never be employed in places where the open sea offers itself as a vast purification tank.

VICTORIA, B. C.:
Printed by RICHARD WOLFENDEN, I.S.O., V.D., Printer to the King's Most Excellent Majesty.
1904.